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Report on the Polish geological investigations in West Antarctica, 1990/91

ABSTRACT: Geological investigations of the 4th Polish Geodynamic Expedition to West Antarctica, summer 1990/91, covered the following topics: volcanological studies and mapping at Deception Island; stratigraphic, palaeonotological and sedimentological studies, and mapping of Tertiary glacial and glacio-marine strata on King George Island; sedimentological and mesostructural studies, and mapping at Hurd Peninsula, Livingston Island; and palaeontological sampling of Jurassic (Mount Flora Formation) and Trinity Peninsula Group deposits at Hope Bay, Trinity Peninsula.

Key words: West Antarctica, regional geology, stratigraphy, sedimentology, tectonics, volcanology, mapping.

Introduction

The 4th Geodynamic Expedition to West Antarctica, summer 1990/91, organized by the Polish Academy of Sciences (leader Prof. Dr A. Guterch) worked in the area of Bransfield Strait from 14 January to 25 February 1991. The main aim of the geophysical party was to complete deep seismic sounding of the Bransfield Strait area, carried already during the 1st, 2nd and 3rd Geodynamic Expeditions of 1978/9, 1984/5, and 1987/8, respectively (*see* Guterch *et al.* 1985; Birkenmajer *et al.* 1990). The geological party consisted of seven men: Prof. Dr. K. Birkenmajer (leader), W. Danowski, Dr M. Doktor, J. Kutyba M. Sc. and Docent Dr A. Tokarski (all from the Institute of Geological Sciences of the Polish Academy of Sciences, Cracow), Docent Dr A. Gaździcki (from the Institute of Palaeobiology of the Polish Academy of Sciences, Warsaw), and R.A. Keller M.Sc. (from the Oregon State University, Institute of Oceanography, Corvallis, Oregon, USA).

The main areas investigated during January and February of 1991 included: (1) Deception Island volcano; (2) King George Bay — Low Head, King George

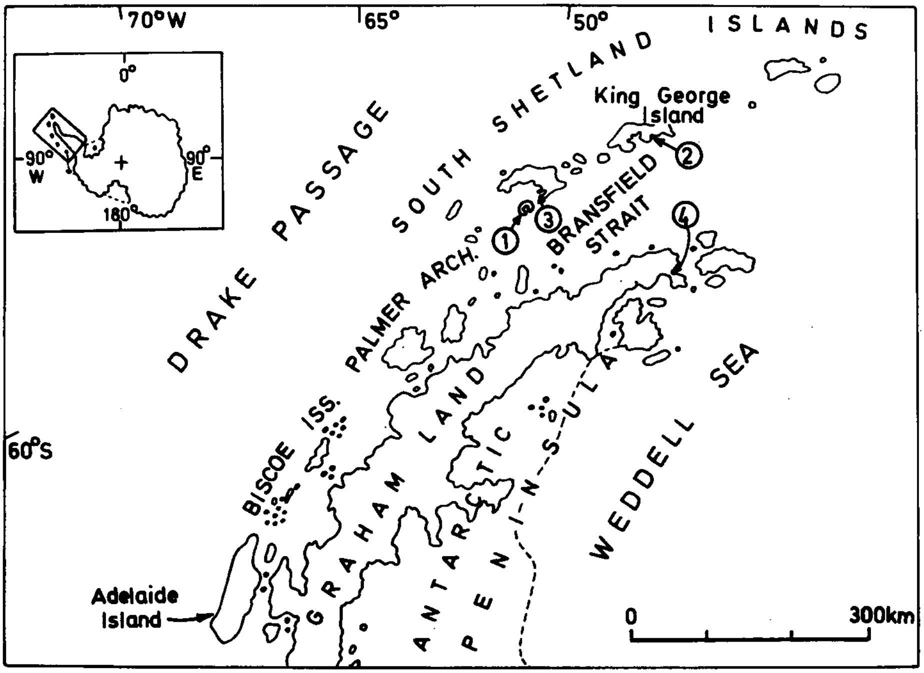


Fig. 1. Key maps to show location of geological investigations of the 4th Polish Geodynamic Expedition, 1990–91, in the Antarctic Peninsula sector, and in Antarctica (inset). 1 — Deception Island; 2 — King George Bay, King George Island; 3 — Hurd Peninsula, Livingston Island; 4 — Hope Bay, Trinity Peninsula

Island; (3) Hurd Peninsula, Livingston Island; and (4) Hope Bay, Trinity Peninsula (Fig. 1). The main aim of the geological field work was to conclude or supplement the studies carried out previously, mainly during the 2nd and 3rd Geodynamic Expeditions (Birkenmajer 1987a, 1988).

Volcanology at Deception Island

The main lines of study carried out by K. Birkenmajer (in the company of W. Danowski, J. Kutyba and R.A. Keller) were directed at: (1) getting more information on the composition of the basement of the volcano; (2) establishing the succession and ages of volcanic events and products; (3) preparing a model of structure and evolution of the volcano.

(1) Basement

Investigation of pelitic to fine-psammitic volcanogenic sedimentary rock fragments obtained in 1985 from volcanic agglomerates at Whalers Bay yielded

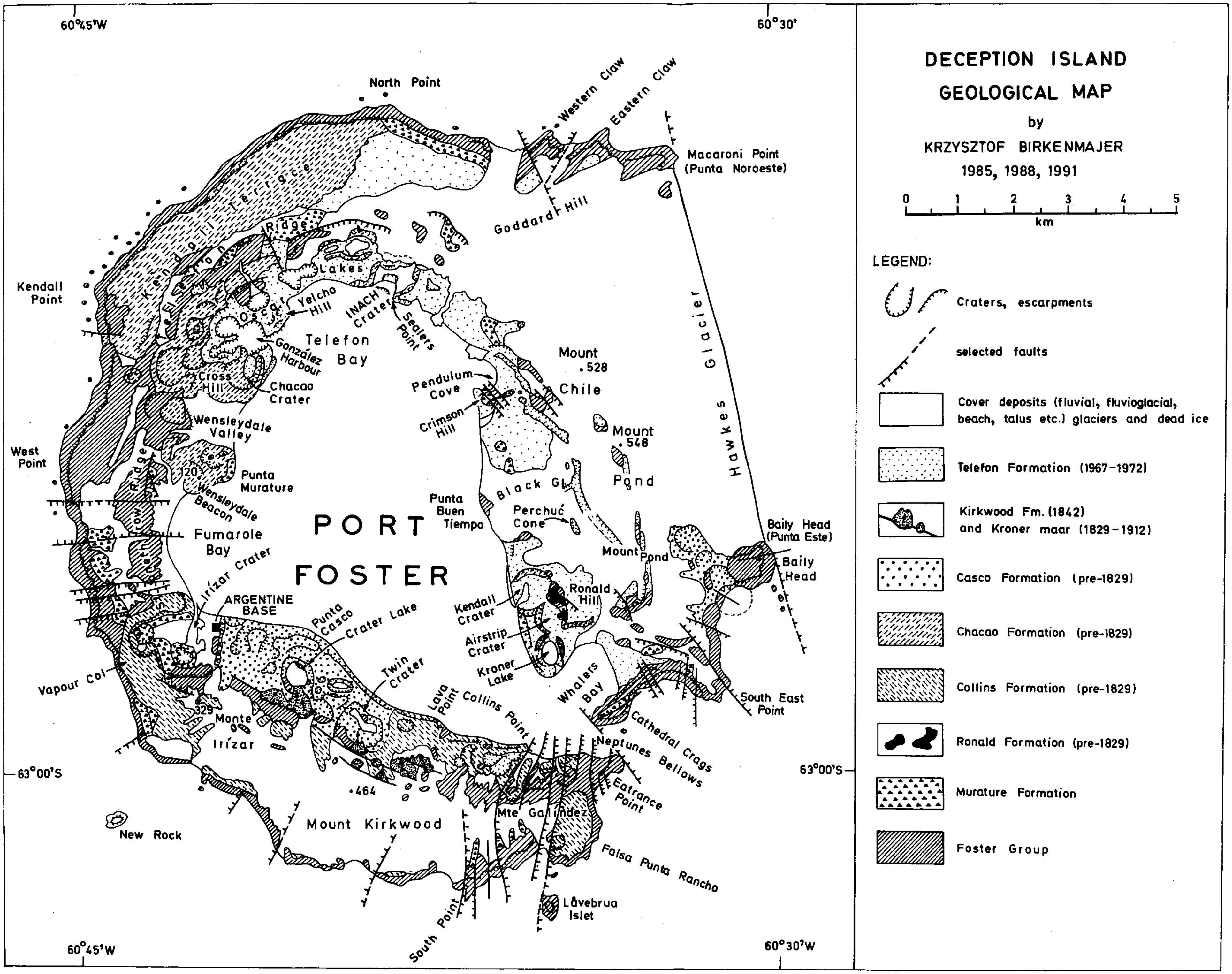


Fig. 2. Geological map of Deception Island

poorly preserved coccoliths of Eocene age (Birkenmajer, Dudziak 1991). This indicates that marine Eocene deposits occur below the Deception volcano.

Futher information on the structure of pre-Eocene basement of the volcano comes from the area of Twin Crater, below Mount Kirkwood. Coarse, yellow-weathered agglomerates belonging to the pre-caldera succession (Foster Group — see below) yielded numerous clasts up to 50 cm in diameter of igneous rocks which may be grouped into: (i) intrusive rocks of gabbroic character ("Andean intrusive suite"); (ii) effusive rocks represented by green to black aphanitic to amygdaloidal basalts, yellowish to whitish acidic rocks, etc. ("Antarctic Peninsula Volcanic Group"). Both groups probably represent a Late Mesozoic to Early Tertiary igneous succession of island-arc type as known from the nearby Livingston, Greenwich, Robert, Nelson and King George islands. Here also belongs a quartz-biotite diorite fragment described from the same locality by Olsacher (1956, pp. 50–52; *see also* Hawkes 1961, p. 24).

(2) Succession and age

During the 1990–91 summer, the field work was centred on the southern part of the island, between Neptunes Bellows and Argentine Base, moreover around Whalers Bay. The geological map, 1:50 000 scale, has been completed, its simplified version being presented as Figure 2. The volcanostratigraphic standard proposed is shown in Table 1. It includes 11 lithostratigraphic units of formation rank assembled in two lithostratigraphic groups, the Foster Group (older), and the Hawkes Group (younger). Structurally, these formations belong to three stages of volcanic evolution of the island: the pre-caldera, the syn-caldera, and the post-caldera stages. They roughly follow subdivision of volcanic rocks on Deception Island as proposed by Holtedahl (1929) and further modified *i.a.* by Olsacher (1956), Hawkes (1961), González-Ferrán and Katsui (1970) and Baker *et al.* (1975). However, both the formation names and their petrologic content shown in Table 1 differ from those used by the previous authors, including the most recent papers by Smellie (1988, 1989, 1990) and Baker (1990). Their equivalents will be discussed site by site in a forthcoming paper where detailed description of field relations will be given.

Geochemical study of rocks from particular formations shown in Figure 2 and Table 1, by R.A. Keller and Prof. M.R. Fisk (Oregon State University, Institute of Oceanography, Corvallis, Oregon), is nearing completion. The petrological names used in this table are based on their work.

The Foster Group (after Port Foster; name introduced by Hawkes 1961) includes all pre-caldera formations of Hawkes (1961) but also some rock-units attributed by him to the post-caldera stage. As a whole, the group represents the stratocone stage of the volcano development. It consists of : (i) lower basaltic and basaltic andesite lavas with subordinate agglomerates

Table 1

Volcanostratigraphy of Deception Island

GROUP	FORMATION	PHASE	FORM	PRINCIPAL PRODUCTS	COLOUR	PETR. TYPE	DATE	VOLC. CYCLE	STAGE
HAWKES (HG)	TELEFON (TF)	GONZÁLEZ (TG)	MAARS	TEPHRA (+ BOMBS & PUMICE)	GREY - GREEN	A	1970	II	POST - CALDERA
		POND (TP)	FISSURE ERUPTIONS	TEPHRA (+ BOMBS) LAVA (SCORIA)	BLACK RED	A	1969		
		YELCHO (TY)	CONES	TEPHRA	GREEN - GREY	A	1967		
	KIRKWOOD (KF)	KRONER (KR)	MAAR	TEPHRA	BLACK	B*	1912 - -1829		
		KIRKWOOD (KK)	FISSURE ERUPTIONS	LAVA (SCORIA) TEPHRA (+ BOMBS)	RED BLACK	B*	1842		
	CASCO (CaF)	EMERALD (CaE)	CONE WITH CRATER	LAVA, TEPHRA	GREY RED	?BA	pre-1829		
		CASCO (CaC)	CONES WITH CRATERS	TEPHRA (+ BOMBS)	BLACK	BA	pre-1829		
	CHAÇAO (ChF)	KENDALL (ChK)	MAARS	TEPHRA	DARK - GREY	(MIX)	pre-1829		
		CHACAO (ChC)	CONES WITH CRATERS	TEPHRA (+ BOMBS)	GREY - GREEN	BA	pre-1829		
	COLLINS (CF)	(CF_2)	CONES WITH CRATERS	TEPHRA	GREY - GREEN	(MIX)	pre-1829	I	
		(CF_1)	LAVA FLOWS	LAVA (+ TEPHRA)	GREY, BLUISH, BLACK, RED	TD	pre-1829		
	RONALD (RF)	(RF_2)	PLUG	PLUG (LAVA)	GREY, BLUISH	TD	pre-1829		
		(RF_1)	LAVA FLOW	LAVA	GREY, BLUISH	TD	pre-1829		
			radial faulting – caldera collapse						SYN-CALDERA
	MURATURE (MF)		DESTROYED RING CONES	TEPHRA (+ BOMBS)	GREY, GREEN	A	pre-1829		
			ring faulting – caldera collapse						
FOSTER	WINDOW (FG_4)		DYKES	DYKE (LAVA)	GREY TO BLACK	TB	LATE-PLEISTOCENE?-HOLOCENE		PRE-CALDERA
	STONETHROW (FG_3)		STRATOCONE	LAVA (+ SCORIA)	GREY, BLACK, RED	BA			
	CATHEDRAL (FG_2)			TEPHRA (+ BOMBS)	GREY, YELLOW WEATHERED	(MIX)			
	ENTRANCE (FG_1)			LAVA (+ SCORIA)	GREY, BLACK, RED	B; BA			

BASEMENT: EOCENE MARINE SEDIMENTS UPON LATE MESOZOIC TO EARLY TERTIARY VOLCANICS AND INTRUSIVES

(*Entrance Formation*); (ii) a thick unit of grey, yellow-weathered, coarse to fine agglomerates (*Cathedral Formation*) often showing large-scale diagonal slope-bedding; (iii) upper basaltic andesite lavas alternating with yellow-weathered agglomerates and lapillistones (*Stonethrow Formation*) — Figs 3–7. These three formations are recognizable over the whole island; they build the outer and crest parts of the island's ring, offshore islets (*e.g.* New Rock; Låvebrua Islet) and downthrown blocks of stratocone structure inside the caldera rim (Fig. 2).

The youngest part of the Foster Group is represented by trachybasalt dykes of small size (*Window Formation*), recognized at Cathedral Crags (Neptune Window) and between Twin Crater and Monte Irízar (Fig. 3, 5C, 6). Such dykes have already been known to Olsacher (1956) and Shultz (1970) but not to Hawkes (1961). They may have intruded at initial stage of ring faulting leading to caldera collapse.

The age of the Foster Group is unknown: it may represent either Late Pleistocene or Holocene.

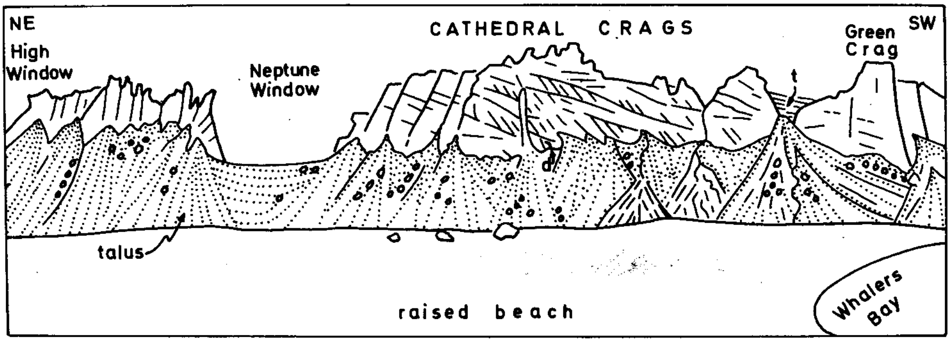
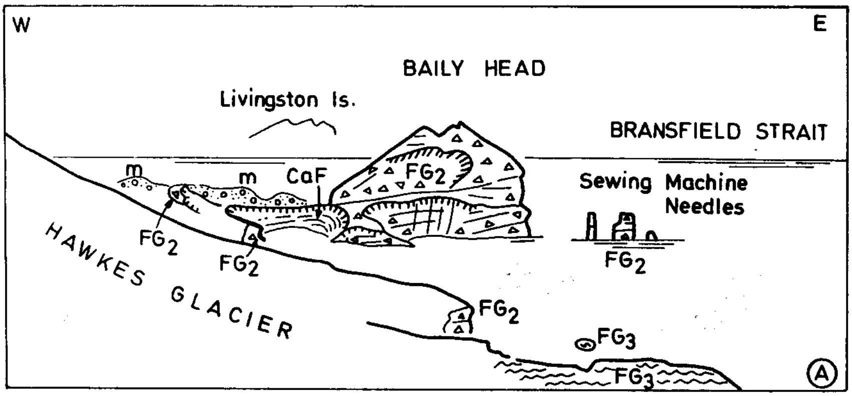


Fig. 3. Exposure of agglomerates of the Cathedral Formation at Cathedral Crags. d — Trachybasalt dyke (Window Formation); t — tuffs of the Murature Formation covered by thin layer of the Telefon Formation (Pond phase) tuffs



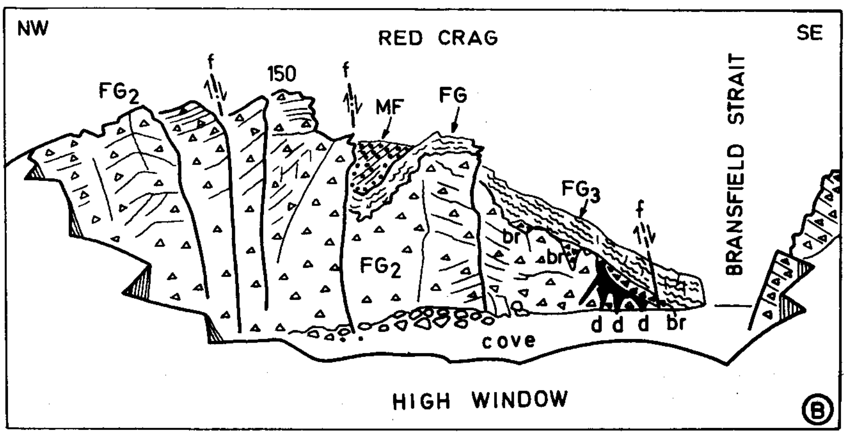


Fig. 4. A — geological panorama of Baily Head; B — geological panorama of Red Crag close to Cathedral Crags (see Figs 2, 3). FG_2 — Cathedral Formation (agglomerates); FG_3 — Stonethrow Formation (basaltic lavas); MF — Murature Formation (lapilli tuffs); CaF — Casco Formation craters; br — volcanic flow breccia; d — basaltic dykes post-dating FG (feeder veins to FG_3 ?); f — faults; m — moraines

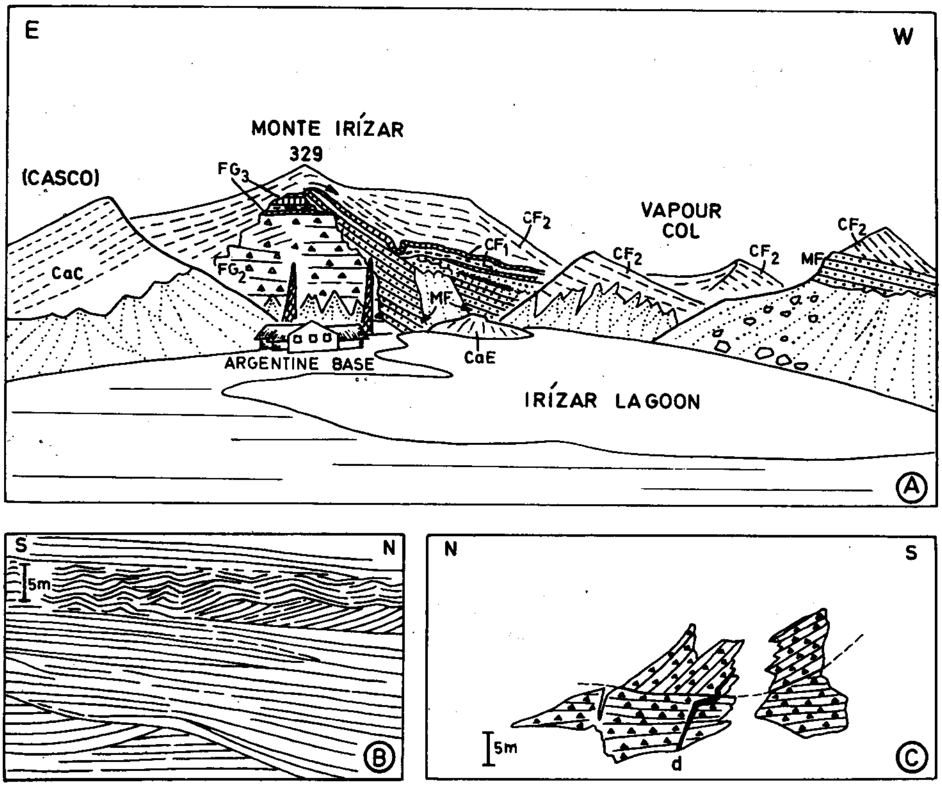


Fig. 5. A — geological panorama of Monte Irízar and its vicinity. FG_2 — Cathedral Formation (agglomerates); FG_3 — Stonethrow Formation (basaltic lavas and tuffs, subordinately agglomerates); MF — Murature Formation (lapilli tuffs); CF — Collins Formation (CF_1 — trachydacite lavas; CF_2 — tuffs); CaC — Casco Formation, Casco phase (tuffs); CaE — Casco Formation, Emerald phase (lavas and tuffs);

B. Detail of large-scale cross-bedding (dune bedding) in the upper part of the Murature Formation at Monte Irízar;

C. Detail showing relation of ?trachybasalt dyke (d — Window Formation) to large-scale cross-bedded agglomerates of the Cathedral Formation below Casco hill (*see* Fig. 6)

The Hawkes Group (after Hawkes Glacier — Fig. 2) includes 7 formations, one of which belongs to the syn-caldera, and the rest to the post-caldera stages. The oldest *Murature Formation* (after Punta Murature — Fig. 2) represents products of andesitic phreatic eruptions, predominantly well-cemented green lapilli tuffs. The formation is spread over the whole island, with fragments of lapilli cones preserved along inner ring faults at Whalers Bay, Pendulum Cove, Sealers Harbour, and Argentine Base. Structurally, the formation seems to be directly related to the caldera collapse along ring faults. It is also probable that flooding of the caldera by the sea through a gap at Neptunes Bellows had occurred already at this stage. The Murature Formation is vertically displaced by both ring and radial faults, as is also the case with the Foster Group.

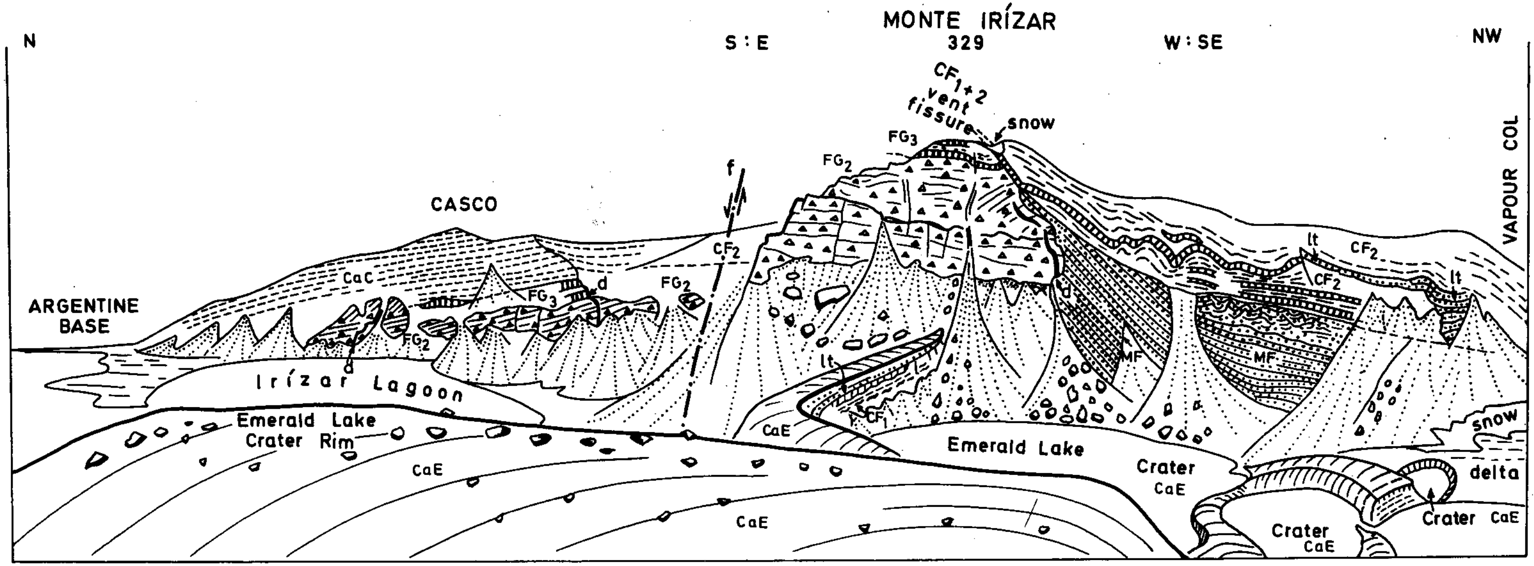


Fig. 6. Close-up of the geological structure of Monte Irízar and its vicinity. Explanations of symbols — as in Fig. 5A-C; lt — lithified tuff

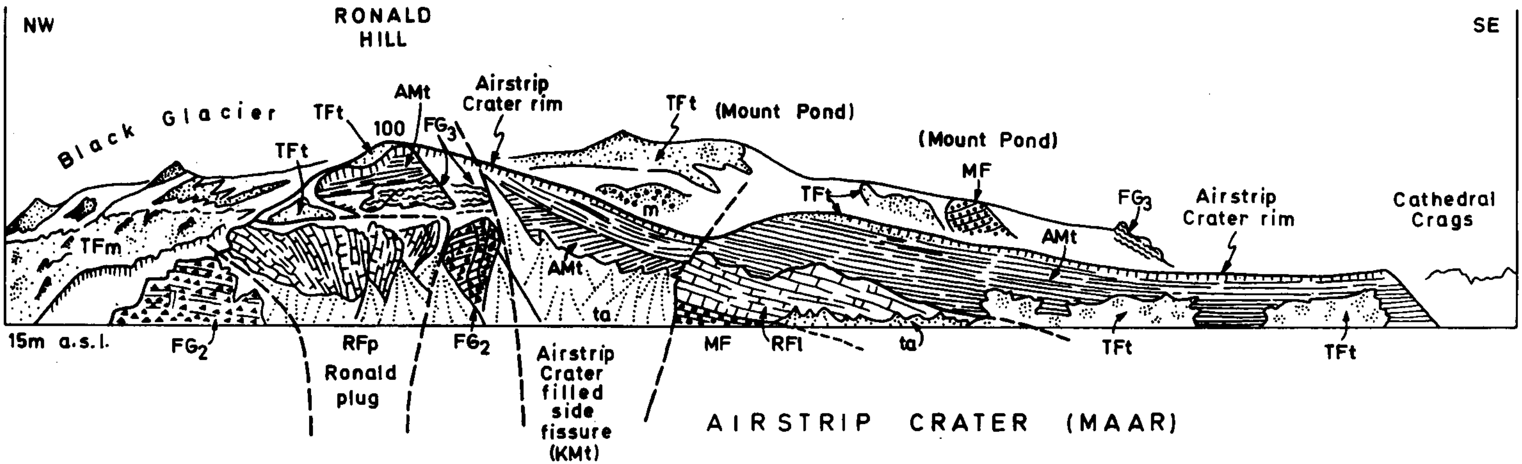


Fig. 7. Geological structure of Ronald Hill. FG_2 — Cathedral Formation (agglomerate); FG_3 — Stonethrow Formation (basaltic lavas); MF — Murature Formation (lapilli tuffs); RF — Ronald Formation (RFp — trachydacite plug; RFl — trachydacite lava); AMt — Airstrip Maar, tuff (Casco Formation); TFt — Telefon Formation (tuff); ta — talus; m — moraine

The *Ronald Formation* (after Ronald Hill, Whalers Bay) is a considerably destroyed small parastitic central volcano, represented by trachydacitic plug and related trachydacitic lava (Fig. 7). Petrographically, it is very similar to the *Collins Formation* which occupies a large area between Entrance Point and Vapour Col, in the southern part of the island (Fig. 8). The *Collins Formation* consists of several thin trachydacite lava flows alternating with scoriaceous lava breccias and tuffs in the lower part, capped by a thicker tuff cover. The tuff-filled craters attributed to the Collins Formation are relatively well preserved, and only partly covered with still younger volcanic products and/or solifluction. The eruptions certainly had occurred prior to 1829, as may be inferred from Kendall's map (*see* Fig. 11A) which shows the coastline between Entrance Point and Fumarole Bay as nearly identical with the present one (Fig. 11B–D).

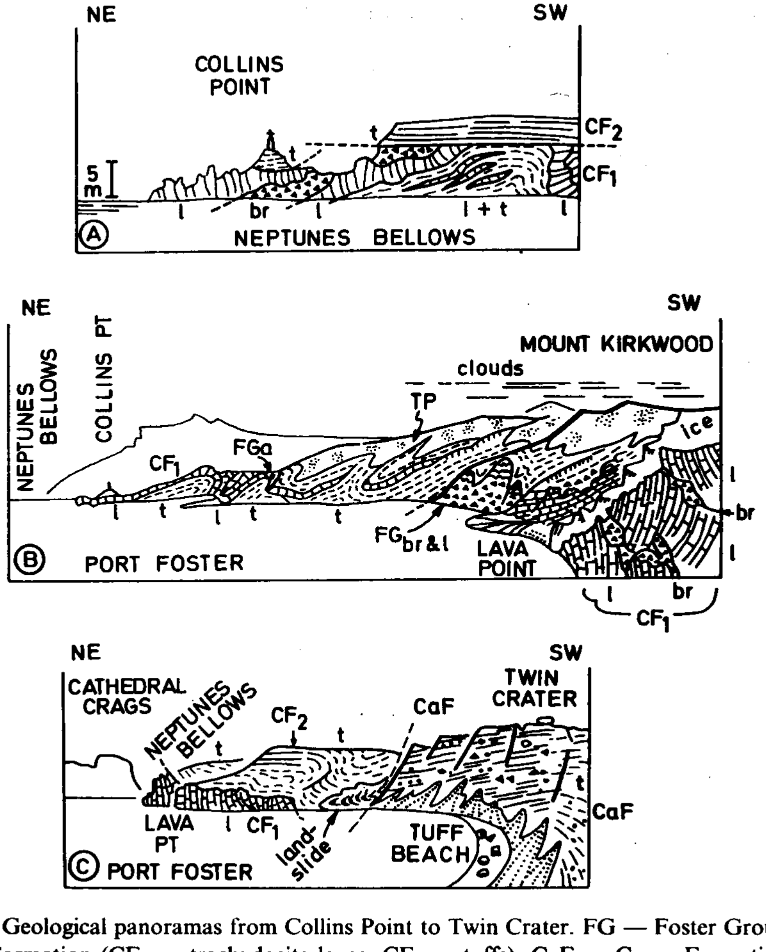


Fig. 8. A-C. Geological panoramas from Collins Point to Twin Crater. FG — Foster Group; CF — Collins Formation (CF_1 — trachydacite lavas; CF_2 — tuffs); CaF — Casco Formation; TP — Telefon Formation, Pond phase (tuffs); a — lava-agglomerate; br — volcanic breccia; t — tuff

The trachydacitic lavas and tephra of the Ronald-Collins formations terminate the first volcanic cycle on Deception Island. That cycle started with basaltic and basaltic andestite eruptions (Foster Group stratovolcano), continued through a trachybasalt dyke intrusion stage (Window Formation) and large-scale phreatic andesite eruptions of parasitic ring volcanoes (Murature Formation), to die-out as trachydacitic effusions and tephra covers. The latter have restricted distribution in the southern part of the island, with eruptive centres and fissures located both inside and outside the caldera rim (Fig. 2).

A new volcanic cycle at Deception Island started with more basic (basaltic andesite) eruptions of the *Chacao Formation* (named after Chacao Crater = Cross Hill). This formation is represented by several comparatively well preserved tephra cones distributed along the inner ring of the caldera, with craters usually opening towards Port Foster lagoon, often flooded by the sea. Such situation is well recognizable on Kendall's map from 1829 (Fig. 11A). The *Chacao Formation* cones occupy the northern half-circle of Deception Island: Wensleydale Beacon, Chacao Crater (= Cross Hill; silted and considerably modified by the 1967–1970 eruptions), Sealers Harbour (silted since 1829, and destroyed during the 1967 activation of the INACH crater — *see* González-Ferrán 1971), and Pendulum Cove (silted since 1829, modified by the 1969 eruption). To the *Chacao Formation* have also been included large maars marked already on Kendall's map (*see* Roobol 1973, 1979): the Kendall Crater and the Irízar Crater (Figs 2, 11).

The *Casco Formation* (after Punta Casco) is represented mainly by pyroclastics, occasionally also by scoriaceous lava of basaltic-andesite character. In the vicinity of Punta Casco, the formation builds several tephra cones with very well preserved craters, either filled with fresh water (*e.g.* Crater Lake) or dry (*e.g.* Twin Crater). The eruption occurred prior to 1829, as may be read from Kendall's map which shows southern coastline of Port Foster between Irízar lagoon and Entrance Point almost identical with the present one. Fresh character of craters might suggest the age of these volcanic forms as probably not exceeding two or three centuries. To the *Casco Formation* have also been attributed some fresh-preserved craters filled with tephra, sometimes also with thin scoriaceous lava flows, below Monte Irízar (Fig. 6: Emerald Lake), near Ronald Hill (Airstrip Crater), and at Baily Head (three craters) — *see* Figure 2. Together with the Punta Casco craters, they mark a southern half-circle of volcanic activity, opposite to that of the *Chacao Formation* cones.

The *Kirkwood Formation* (after Mount Kirkwood) occupies a small area on northern flanks of Mount Kirkwood and Monte Irízar. It forms an arc 4.5 km long situated just inside the caldera rim. This is a series of at least 11 small craters filled with red basaltic scoria linked by several parallel fissures up to 10 m wide, and 0.75 to 3.8 km long (Fig. 9). Following arguments presented by Roobol (1973), the present author dates these eruptions at 1842 when a sealing captain W.H. Smiley had observed that "the whole south side of Deception Island appeared as if on fire. He counted thirteen volcanoes in action" (Roobol 1973, p. 23). The Kirkwood Formation post-dates the *Casco Formation*, as it is well seen in Crater Lake (Birkenmajer 1991; *see also* Hawkes 1961, Fig. 10). Lichenometric dating, using single circular thalii of *Rhizocarpon geographicum*, has been performed on a large glacially polished block of older lava jutting out of red basaltic scoria which fill the 1842 crater above Crater Lake. The largest thalii diametres were 19–21 mm. Taking into account that this lichen grows on a nearby Livingston Island at a rate of 13.5 mm per century (Curl 1976; *see also* Birkenmajer 1980a, 1982a), the age of the largest thalii measured is about 150 years. This value gives a surprisingly good confirmation of the age of the Kirkwood eruption as being very close to 1824 (Birkenmajer 1991).

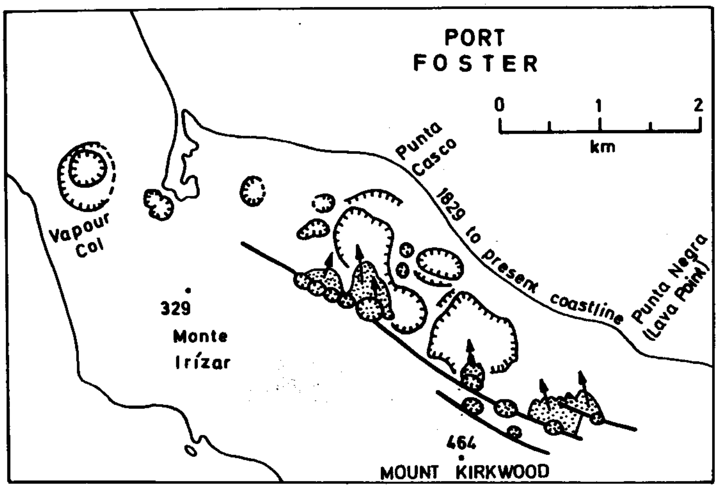


Fig. 9. Distribution of the 1842 eruptive centres (Kirkwood Formation) below Monte Irizar and Mount Kirkwood: craters barbed and dotted; scoriaceous basalt lava flows dotted (arrows indicate flow direction); eruption fissures marked by heavy lines. Craters of the Casco Formation marked in the background

To the *Kirkwood Formation* has also been attributed the Kroner Lake crater at Whalers Bay which is filled with basaltic pyroclastics (see Hawkes 1961); the crater had formed between 1829 and 1912 (it is not marked on Kendall's map — *see* Barrow 1931, and Fig. 11A).

The *Telefon Formation* (after Telefon Bay) is represented by three phases: the Yelcho tephra cones (1967), the Mont Pond fissure eruptions with tephra and scoria (1969), and the González maars with tephra (1970). The course and products of these eruptive phases are well described in a number of papers (*e.g.* Baker *et al.*, 1975; González-Ferrán and Katsui 1970; González-Ferrán 1971; Orheim 1972; Roobol 1973, 1979, 1982). Both the tephra and scoria are andesitic in character. A steaming cinder cone (Fig. 10) which occurs at the southern end of the 1969 volcanic fissure system at Mount Pond (Birkenmajer 1987) is the last "hot evidence" of that eruption on the southern flank of the mountain. It did not change either its form or type of activity between 1985 and 1991.

(3) Structure and evolution

A preliminary model of structural evolution of the Deception Island volcano, points to the following conclusions:

(i) The Foster Group rocks represent remnants of a large central stratovolcano, probably between 20 and 30 km in diameter at its submarine base, with slopes rising at 15–20 degrees probably to about 2500 m above sea level. Strong predominance of coarse agglomerate to lapilli agglomerate, the products of violent explosions, over lava flows, is compatible with predominantly basaltic-andesitic character of magma, rich in volatiles. According to the present author, there are no good evidences for the presence of a shield-type basaltic volcano at this pre-caldera stage. There is also no convincing evidence for submarine cooling of the lavas which would result in the formation of basaltic pillow-lavas and hyaloclastites at the time of formation of the Foster Group, as reported by some authors;

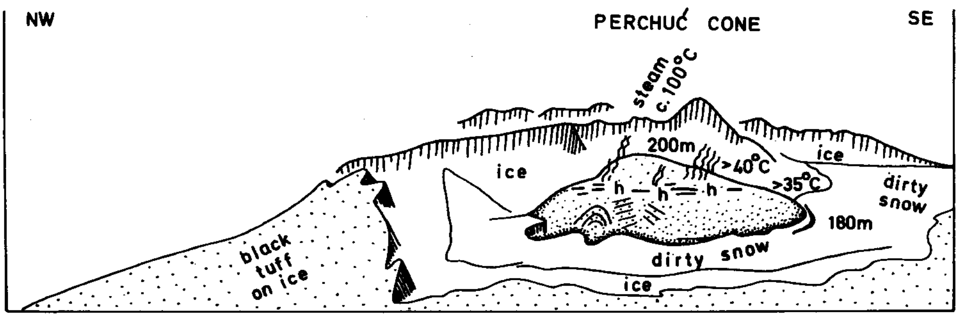


Fig. 10. Perchuć Cone at the southern termination of the Mount Pond eruption fissures (Telefon Formation, Pond phase); h — hot spots (temperature about 100°C). Figure drawn in 1985

(ii) The collapse of the caldera occurred along concentric faults (ring faults). Its initial stage was marked by the appearance of small trachybasaltic dykes intruded probably mainly along incipient ring fractures;

(iii) The flooding of the caldera through a gap at Neptunes Bellows had occurred probably simultaneously with the collapse; this gap was a weak zone in the stratovolcano structure as may be guessed from a dense pattern of gravity faults between Entrance Point and Cathedral Crags (Fig. 2). A Krakatoan-type explosion caused by sea water violently vaporizing on entering hot magma chamber, cannot be ruled out. Phreatic character of the Murature Formation eruptions (andesite lapilli tuffs lithologically comparable with those of the 1967 Yelcho phase), and location of the Murature cones along inner side of the caldera rim, would support the above assumption;

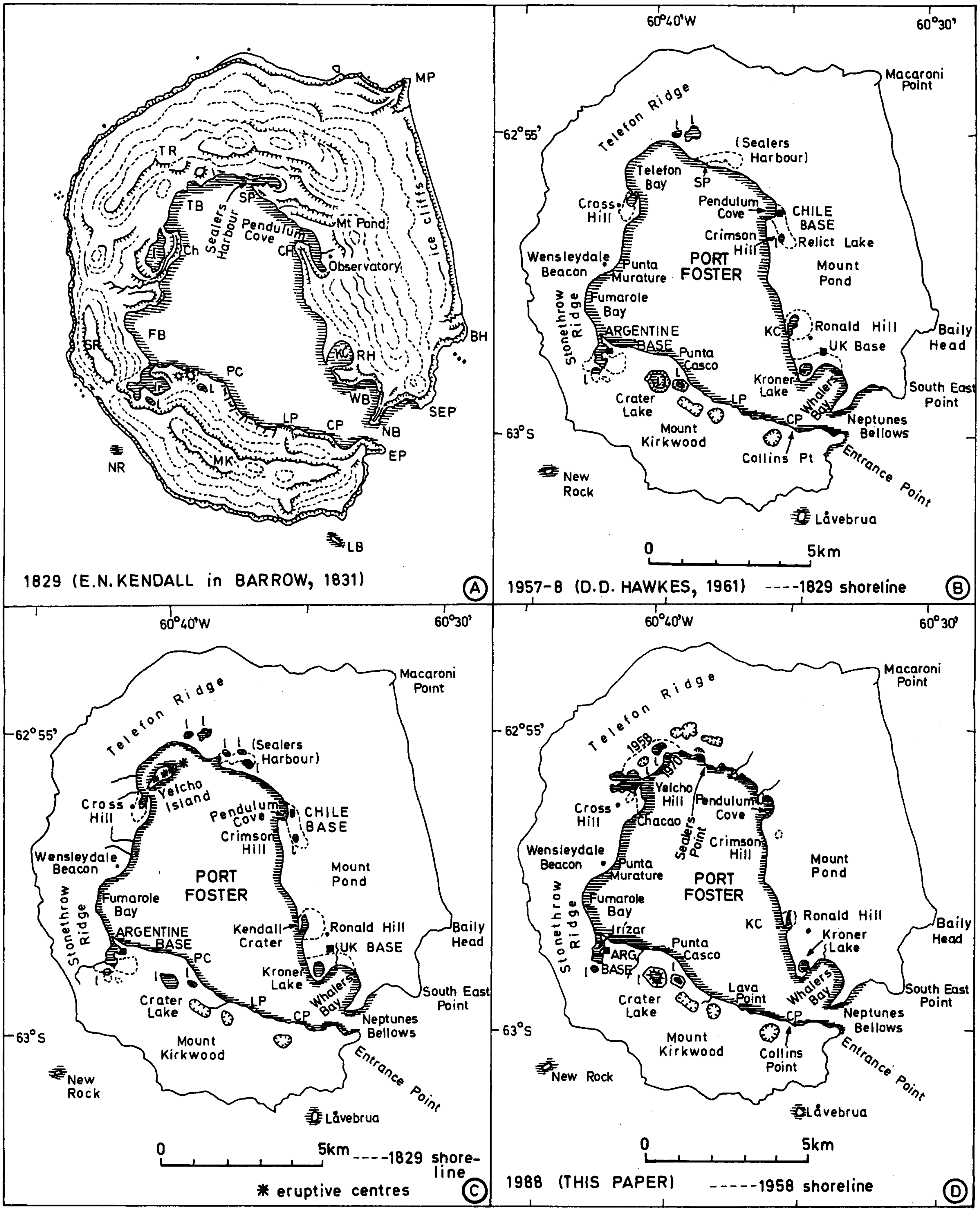


Fig. 11. Deception Island: A — in 1829 (*after* Kendall, in Barrow 1831); B — in 1957—58 (*after* Hawkes 1961); C — in 1968 (Brit. Antarct. Territory, topographic map, 1:200,000, sheet W 62 60); D — in 1988

(iv) Ring- and radial faulting had displaced the Murature Formation, and the Foster Group as well, already before the onset of the post-caldera parasitic cone systems. The latter are not displaced by faults;

(v) Further subsidence of the caldera had proceeded in a sectorial manner, involving successively: the southern sector (Collins-Ronald formations); the north-western sector (Chacao Formation); the southern and south-eastern sectors (Casco and Kirkwood formations); finally, the north-western, northern and eastern sectors, in the succession (Telefon Formation). Orheim (1972, p. 120) suggested a clockwise progression of caldera subsidence during the recent eruptions (1967–1969);

(vi) A new (2nd) volcanic cycle was initiated with the Chacao Formation basaltic-andesitic tephra, following upon trachydacites (Ronald-Collins formations) of the close of the first cycle (Table 1). The magma character has changed since, to become at present andesitic in composition (Telefon Formation);

(vii) Appearance of the NNW-SSE-trending Hawkes fault (at the eastern termination of Hawkes Glacier — Fig. 2), already prior to 1829 (see Fig. 11A), probably coincided with the Casco Formation. This is indicated by a series of explosive centres near Baily Head aligned subparallel to that fault. A similar line may be traced in the succession of craters: Kendall Crater (Chacao Fm.) — Airstrip Crater (Casco Fm.) — Kroner Lake (Kirkwood Fm.). The course of explosive tension gashes which opened in 1969 at Mount Pond (*see* Fig. 2) also follows a similar trend. They may have opened as a result of sinistral strike-slip displacement along a NNW-SSE-trending fault subparallel to the Hawkes fault. This displacement may reflect a strike-slip regime in wider surroundings of the Hero Fracture Zone;

(viii) The Yelcho phase (1967–70) reflected a renewal of caldera subsidence in the northern sector, and the Pond phase (1969) — a strike-slip displacement, subparallel to the Hero Fracture Zone, of the eastern part of the volcano. The latter resulted in opening of NW-SE-oriented eruptive tension-gashes at Mount Pond (eastern sector — Fig. 2), and also of NE-SW-oriented non-eruptive tension-gashes between Stonethrow Ridge and Vapour Col (western sector), as reported by Shultz (1972);

(ix) The present author did not find structural evidence for possible influence of the SW-NE-aligned Bransfield Rift volcanic system on distribution of alkaline volcanism on Deception Island.

King George Bay — Low Head area

The geological work in that area concentrated mainly on: (1) detailed geological mapping of Early Tertiary and Quaternary rocks (K. Birkenmajer); (2) study of lithostratigraphic boundaries and facies differentiation in Early Tertiary glacio-marine and continental glacial deposits (K. Birkenmajer).

(1) The detailed geological mapping to a 1:5000 scale, with a topographic map at the same scale (Battke and Cisak, 1988) as a background, covered coastal area between Sukiennice Hillls — Lions Rump and Mazurek Point (MP III — Fig. 12). The rocks mapped included two lithostratigraphic units of Early Tertiary age, the Polonia Glacier Group (probably Eocene — *see* Birkenmajer 1981; Birkenmajer *et al.* 1991), and the Chopin Ridge Group (Birkenmajer 1980b, 1982b, 1987b) of Oligocene age.

Lichenometric method, using *Rhizocarpon geographicum* thalii as a medium, was applied to date the oldest marginal moraines of White Eagle Glacier. With the largest thalii of 30, 25, 20 and 19 mm in diameter and using a 13.5 mm per century growth rate of this lichen as established on Livingston Island by Curl (1976), the age of these moraines may be calculated as exceeding 220 years; they had formed prior to 1770 AD. There is a series of terminal and marginal moraines of younger generation, and a small marginal recession moraine of quite recent origin (formed between 1979 and 1991).

(2) Due to continuous glacier retreat during the past 12 years (since 1979), new rock exposures have emerged from the ice in front of White Eagle Glacier:

(i) The first one, in a waterfall at the main stream of the discussed area, the Muddy Creek, shows basal agglomerates of the Sukiennice Hills Formation resting unconformably upon the Lions Cove Formation. The latter is represented by red tuffaceous clays with streaks of yellow arkosic sandstones resting upon weathered andesite lava. The superposition of the Sukiennice Hills Formation upon the Lions Cove Formation postulated earlier (Birkenmajer 1981), is thus proven;

(ii) A series of new exposures along the northern margin of White Eagle Glacier, west of the waterfall, show various members of the Polonez Cove Formation resting directly upon the Mazurek Point Formation basaltic lavas. Two exposures between the waterfall and Sukiennice Hills show very coarse beach-type conglomerates of the Low Head Member, with well- to very-well rounded basalt boulders up to 1.5 m in diameter (*cf.* Birkenmajer 1982b, p. 35: "5"). Another exposure, at the westernmost margin of the 1:5000 map, south of Sukiennice Hills, shows a steep wall of the Mazurek Point basaltic lavas overlain by fossiliferous glacio-marine deposits of the Polonez Cove Formation (Low Head Member);

(iii) A new exposure of diamictite (continental tillite) of the Krakowiak Glacier Member (basal part of the Polonez Cove Formation, Lower Oligocene) was found in vertical cliffs immediately south of Battke Point: the diamictite fills there a large erosional depression in the Mazurek Point Formation basaltic lavas, and is overlain by the Low Head Member basaltic conglomerates showing giant foresets (Fig. 13);

(iv) A section of the Polonez Cove Formation, some 90 m thick, in the northern part of Mazurek Point (MP III-IV), exposed in the past 12 years due to

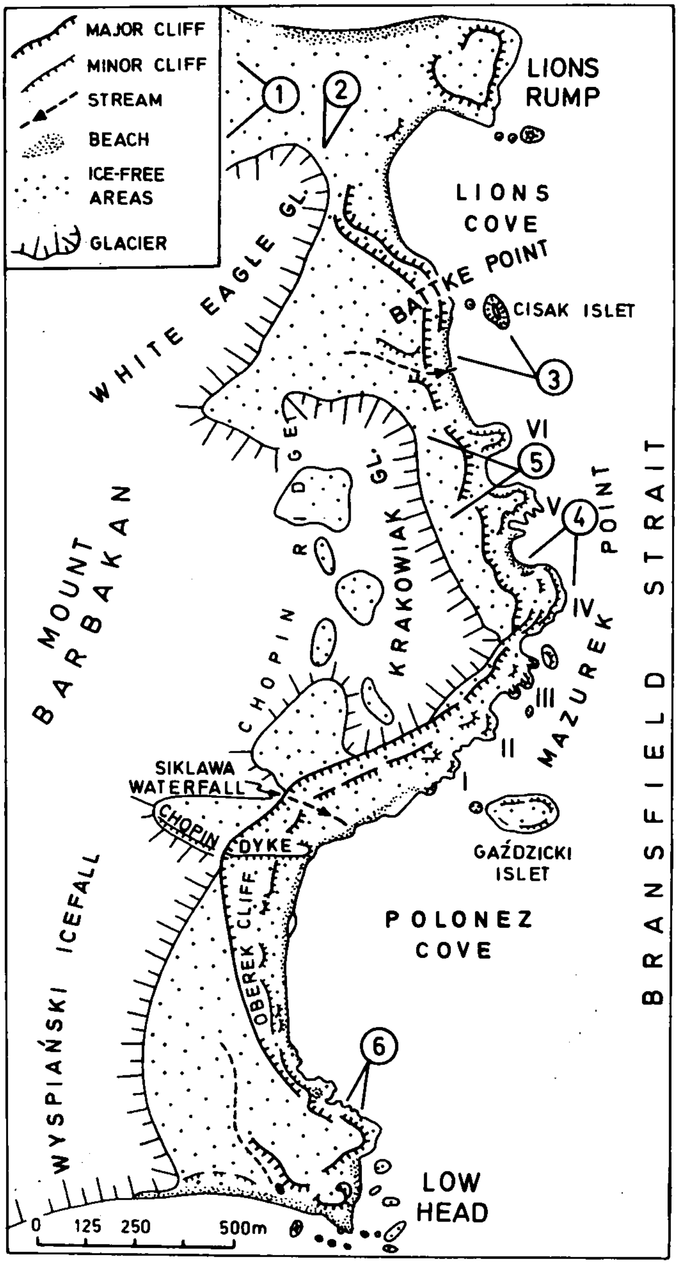


Fig. 12. Location of geological investigations and palaeontological sampling between Lions Rump and Low Head. I–VI — Mazurek Point promontories; 1 — Sukiennice Hills area and margin of White Eagle Glacier (left of the figure); 2 — waterfall at Muddy Creek; 3 — Battke Point (*see* Fig. 13); 4 — Mazurek Point IV (*see* Fig. 14); 5 — margin of Krakowiak Glacier — Chlamys Ledge (*see* Fig. 15); 6 — Low Head (*see* Fig. 16)

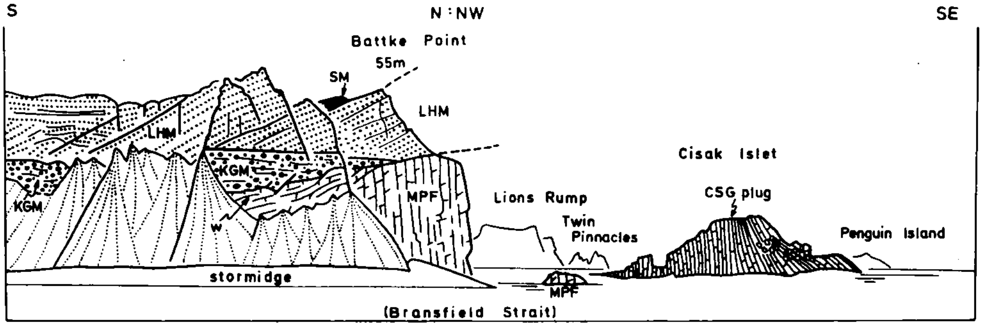


Fig. 13. Exposures in cliff at Battke Point (*see* Fig. 12). MPF — Mazurek Point Formation (columnar basaltic lavas; w — weathered in upper part below KGM). Polonez Cove Formation: KGM — Krakowiak Glacier Member (diamictite); LHM — Low Head Member (basaltic conglomerate, giant foresets); SM — Siklawa Member (shales and siltstones). CSG — Cape Syrezol Group

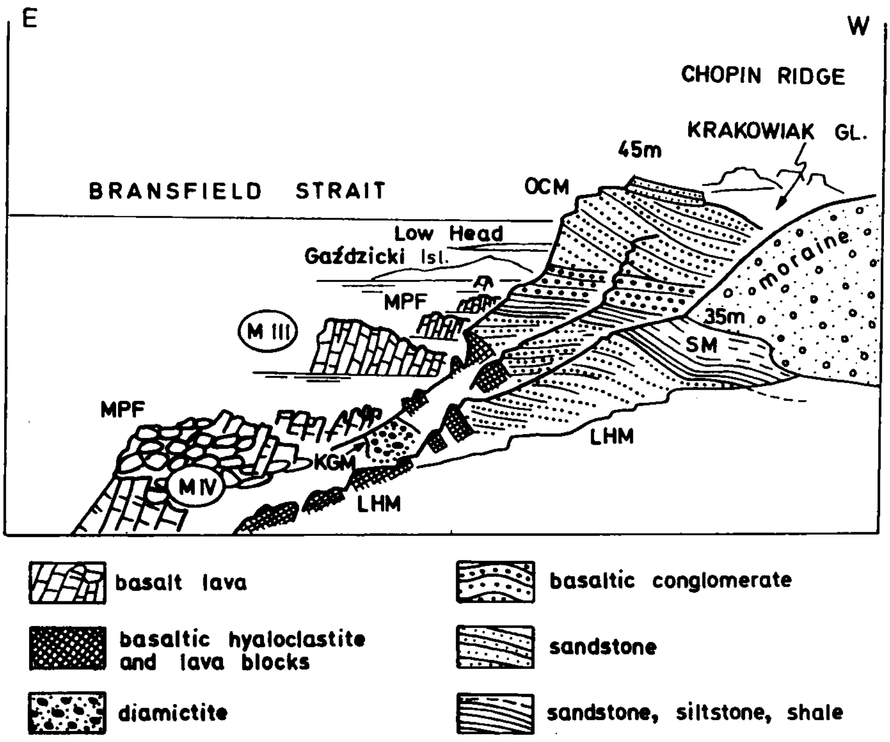


Fig. 14. Geological panorama of Mazurek Point IV and vicinity, as seen from the north (*see* Fig. 12). MIII, MIV — Mazurek Point. MPF — Mazurek Point Formation (columnar basaltic lavas). Polonez Cove Formation: KGM — Krakowiak Glacier Member; LHM — Low Head Member; SM — Siklawa Member; OCM — Oberek Cliff Member

a considerable retreat of Krakowiak Glacier, was studied in detail. The basement of the Polonez Cove Formation is there formed, as usual, by basaltic lavas of the Mazurek Point Formation (Upper Cretaceous). There follow diamictites of the Krakowiak Glacier Member, and glacio-marine and volcanic units of the Low Head, Siklawa and Oberek members. The Low Head Member begins with basaltic hyaloclastite which at places shows relics of original basaltic lava flow structure (Fig. 14); there follow fossiliferous basaltic conglomerates with numerous exotic dropstones (ice-rafted material), with poorly marked bedding. The Siklawa Member is represented by alternating fine-grained sandstones and shales. The Oberek Cliff Member begins with angular basaltic conglomerate which is followed by basaltic hyaloclastite alternating with basaltic lava flows (*see* Birkenmajer 1990); the hyaloclastite locally passes into basaltic conglomerates showing giant foresets (Fig. 14; *see also* Porębski and Gradziński 1987, 1990); higher up, there appear horizontally bedded fossiliferous green basaltic sandstones and fine conglomerates; finally, there come light-grey to pinkish, fine- to medium- and coarse-grained massive arkosic sandstones with parallel horizontal streaks of coarse sandstone and fine polymict conglomerate. The appearance of feldspar and various tuff and porphyrite clasts in the sandstones, indicates that they had formed simultaneously with the first eruptions of the Boy Point Formation volcanics. Thus, they may be regarded as the youngest deposit of the Polonez Cove Formation. The sandstones in question contain numerous poorly preserved pectinids (*Chlamys* sp.), mainly as impressions and moulds visible at parting surfaces of the rock. There follow porphyritic lavas, agglomerates and tuffs of the Boy Point Formation (Oligocene — Fig. 15);

(v) Basal basaltic breccias of the Polonez Cove Formation have been re-examined at Low Head. Their hyaloclastite character alternatively suggested by Birkenmajer (1982b, p. 26: "4"), proven by studies of Porębski and Gradziński (1987, 1990) and Tokarski (1987, pp. 127–129), is now firmly established. Relics of a primary basaltic lava flow which gave rise to the hyaloclastite were recognized in the exposure (Fig. 16): we see there load-casted, bulbous base of the flow, at places disintegrating into pseudo-pillows (as observed by Tokarski 1987, Fig. 7). Disintegration of the lava flow to hyaloclastite most probably occurred in shallow marine environment at the onset of marine transgression of the Low Head Member. The eruptive center of the basaltic lava could have been located to the south of Low Head.

Hurd Peninsula, Livingston Island (by *M. Doktor* and *A.K. Tokarski*)

Geological mapping, lithologic-sedimentological and structural studies have been carried out on Hurd Penisula, Livingston Island, between Johnsons Dock and Miers Bluff, partly also along the eastern coast of the peninsula, immediately north of Miers Bluff. The rocks studied included a thick clastic sequence of the

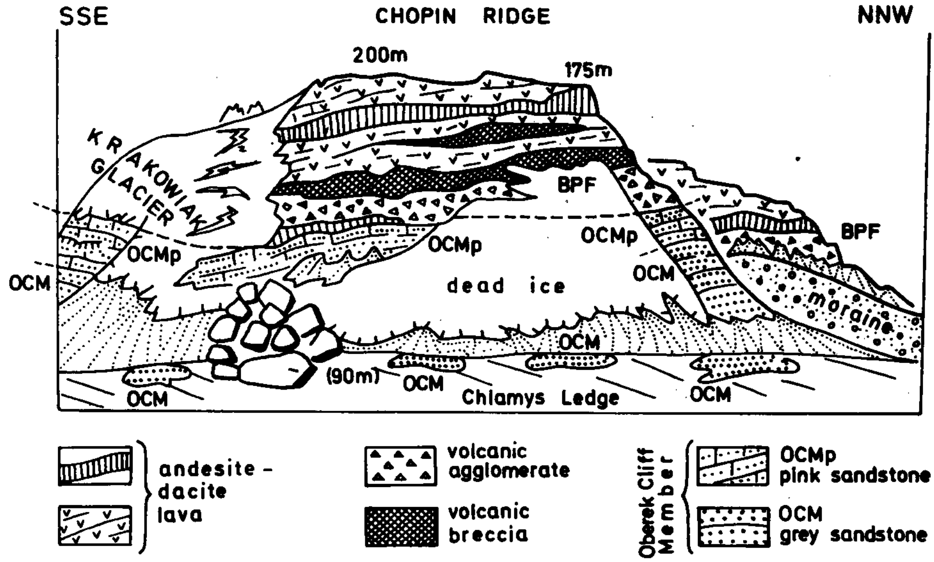


Fig. 15. Exposure of the Polonez Cove Formation (OCM — Oberek Cliff Member, uppermost part) and the Boy Point Formation (BPF — volcanics) at the margin of Krakowiak Glacier (*see* Fig. 12)

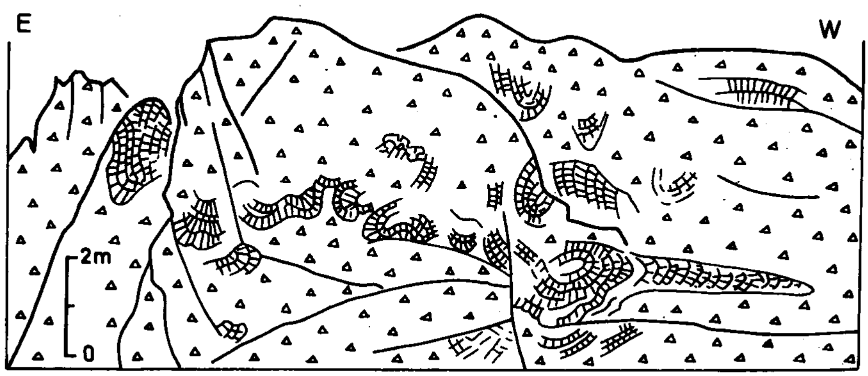


Fig. 16. Exposure of basaltic hyaloclastite with relics of original lava flow structures at Low Head (*see* Fig. 12). Polonez Cove Formation, Low Head Member (lower part)

Trinity Peninsula Group designated as the Miers Bluff Formation, and small intrusive mafic bodies.

Trinity Peninsula Group (?Carboniferous — ?Triassic). Cumulative thickness of the Trinity Peninsula Group on Hurd Peninsula, known here as the Miers

Bluff Formation (MBF), attains about 2200 m, out of which over 1600 m thick column was studied in detail. Dalziel (1972) estimated the MBF thickness as exceeding 3000 m. Three lithofacies have been distinguished:

(i) Thick-bedded sandstone units. The sandstones are usually fine-grained, less commonly medium-grained, massive, often amalgamated, 1.5 or more metres thick. They show normal graded bedding (seldom recognizable) and often contain numerous shale clasts; the latter often accumulate in larger amounts giving rise to intraformational shale breccia. Traces of large-scale cross-bedding are visible at places. No macroscopic organic remains have been found. Taking into account the above characteristics, as well as good sorting of quartz grains, a turbidite and/or grain flow origin of the sandstones is suggested;

(ii) Medium-bedded fine-grained sandstones (layers 0.5–1.5 m thick) alternating with black shales, sometimes also with intraformational shale-flake conglomerates. There is a variety of sedimentary structures recognizable: mainly load casts of variable size, and traces of ripplemarks. No macroscopic plant or animal remains have been found. The origin of this lithofacies was probably related to turbidity currents of diversified density, while frequent traces of submarine slumping of whole layers or sets of layers point to instability on reservoir bottom;

(iii) Thin-bedded massive fine-grained sandstones and siltstones alternating with claystones and shales, olive-grey to black in hue. These are typical rhythmites formed by quiet deposition from low-density turbidity currents and suspension clouds. Trace fossils are here frequent, ripplemarks, load-casting, horizontal and wavy lamination are distinctive sedimentary features of the deposits.

The (i) to (iii) lithofacies are generally devoid of calcium carbonate. Subaquatic slumping of sediments, most frequent in the (i) and (ii) lithofacies, involves sets up to 40 m thick. The above sedimentary characteristics resembles that described from the Hope Bay Formation (Trinity Peninsula Group) at Hope Bay, Trinity Peninsula, by Birkenmajer (1988).

Tectonics and mafic intrusions. The MBF rocks represent a tectonically reversed unit monoclinally dipping at 20–40 degrees due west. The monocline is secondarily disturbed by two flexures whose axes are parallel to the strike of the monocline (N30E). The strata in the flexure zones locally retain normal (i.e. tectonically not overturned) dips.

Mesostructural studies show that brittle deformation had occurred in three successive stages (1–3):

(1) During the first stage, of N-S-oriented horizontal compression, have been successively formed: (i) two sets of vertical shear-joints oriented symmetrically about a N-S direction (strike-slip faults follow along these planes); (ii) swarms of vertical quartz veins also oriented N-S, usually showing copper mineralization traces; (iii) subvertical N-S-oriented mafic dykes and sills;

(2) During the next stage, of W-E-oriented horizontal compression, have been formed: (i) two sets of vertical shear-joints oriented symmetrically about a W-E-direction; (ii) two sets of strike-slip faults showing a similar orientation; (iii) a set of subvertical mafic dykes oriented W-E;

(3) During the final stage, reorientation of movement occurred on some of strike-slip fault planes formed during the previous stages (1 and 2).

No dating of the above deformation phases has as yet been possible.

Palaeontology (by *A. Gaździcki*)

Palaeontological work was carried out at Hope Bay, Trinity Peninsula (Antarctic Peninsula), and at Kraków Peninsula, King George Island, between King George Bay and Low Head (Figs 1, 12).

At Hope Bay, fossil plants have been collected from the Mount Flora Formation (Middle Jurassic), mainly from scree and Quaternary moraines, between 20 January and 7 February, 1991. Samples for micropalaeontological study have been collected from shales of the Hope Bay Formation, Trinity Peninsula Group (?Permian-?Triassic).

On King George Island, palaeontological work carried out between 8 and 22 February, 1991, included:

(i) Sampling of fossils from glacially-controlled marine strata of the Polonez Cove Formation (Lower Oligocene), mainly from the Low Head Member. Of special interest is the collection of stromatolites, benthic foraminifers, sponges, corals, bivalves (*e.g.* from the genus *Panopea*) echinoids and brachiopods. Solitary corals of the genus *Flabellum* have been collected from the lowest part of the Low Head Member exposed in a cliff at the north-west margin of White Eagle Glacier; this is the earliest record (Early Oligocene) of this coral genus from Antarctica.

(ii) Sampling of poorly preserved *Chlamys* shell imprints (Bivalvia), and better preserved brachiopod shells, was carried out at a new exposure of the highest strata of the Oberek Cliff Member (sandstones), recently found by British geologists M.R.A. Thomson and C. Bryer in front of receding Krakowiak Glacier.

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Streszczenie

Badania geologiczne 4. Wyprawy Geodynamicznej do Antarktyki Zachodniej (lato antarktyczne 1990/91) obejmowały następujące zagadnienia w sektorze Półwyspu Antarktycznego — Szetlandów Południowych: studia wulkanologiczne i kartowanie geologiczne w skali 1:50 000 wulkanu Deception Island; badania stratygraficzne, paleontologiczne i sedymentologiczne oraz wykonanie zdjęcia geologicznego w skali 1:5 000 utworów glacjalnych i morsko-glacjalnych oligocenu (formacja Polonez Cove), ich podłoża (wulkanity formacji Mazurek Point) i nadkładu (wulkanity formacji Boy Point), oraz trzeciorzędowej grupy Polonia Glacier na Wyspie King George (King George Bay — Low Head); studia sedymentologiczne i mezostrukturalne oraz wykonanie zdjęcia geologicznego na Półwyspie Hurd (Wyspa Livingston); studia paleontologiczne w rejonie Hope Bay na Półwyspie Trinity (zbieranie okazów jurajskiej flory; pobieranie próbek do badań palinologicznych z utworów klastycznych grupy Trinity Peninsula — ?perm-trias?).